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BEHAVIORAL FOUNDATIONS OF DECISION ANALYSIS

Paul Slovic

Oregon Research Institute

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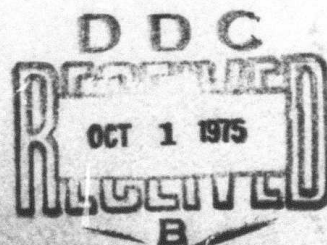
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# ONR Technical Report

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## BEHAVIORAL FOUNDATIONS OF DECISION ANALYSIS: FINAL REPORT

Paul Slovic



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14. ABSTRACT <b>This paper summarizes the work done under Contract N00014-73-C-0438 in the areas of:</b> <ul style="list-style-type: none"><li>a. probability assessment, prediction and choice</li><li>b. evaluation of past decisions</li><li>c. decision theory.</li></ul> <b>Twelve completed reports and six studies in progress are described.</b>			

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OREGON RESEARCH INSTITUTE

Behavioral Foundations of Decision Analysis: Final Report

Paul Slovic

August, 1975



# Final Technical Report: Decision Analysis Research

Paul Slovic

Oregon Research Institute

## A. Research Objectives

The research conducted under the concluding contract has explored problems man faces when integrating information about his uncertain world, evaluating past decisions, and anticipating future events. We have systematically compared what decision makers are doing with information to what they should be doing, and we have begun to develop tools to help people become better decision makers.

## B. Summary of Research Accomplishments

1. Probability Assessment, Prediction, and Choice: Systematic biases in unaided human judgment. Much is known about how probabilities ought to be assessed--the mathematical constraints. However, little has been known about how probabilities are assessed by people whose cognitive constraints limit their ability to perform optimally. In our research, we have discovered several heuristics used by probability assessors; heuristics which simplify the cognitive strains of the task, but which can lead to serious distortions or biases in the assessments made. While much of this research has its origins in laboratory studies, the implications of the research for practical, applied problems have been widely recognized.

We have found that predictions, too, are prone to systematic biases. For example human predictions are overwhelmingly determined by specific, individuating information rather than base-rate information reflecting a large data base. Our research has also shown that

people making numerical predictions from numerical cues are fundamentally non-optimal, and that their ability to process multivariate information is highly limited and often biased. These findings lead to grave concern about the adequacy of unaided human judgment, suggesting that judges should receive specialized training, or else be aided by, or sometimes replaced by, computers.

When people are called upon to choose among well-specified alternatives their preferences may often be subject to bias. We have shown that in some situations, their choices violate one of the fundamental axioms of rational decision making. Further, we have shown that difficult choices, between alternatives which are equated in value, are resolved in predictable, but not optimal, ways.

2. Evaluation of Past Decisions: The psychology of hindsight and evaluation. Work performed under the present contract has provided a new view of how people evaluate the past, showing that people perceive past events as having been far more inevitable, in hindsight, than such events seemed before they occurred. Far-reaching implications of this work are: (a) evaluations of the past performance of decision makers may be unduly harsh in stating that "you should have known what would happen;" and (b) because the past seems more predictable than it was, humans are unable to learn to anticipate the surprises of the future.

3. Theory Development. A portion of the effort under the contract has been devoted to examining the adequacy of utility theory as a normative and descriptive theory of decision-making behavior. We have found that utility theory does not provide an adequate description of people's behavior in the face of uncertainty. These results bring into question the adequacy of the procedures used in decision analysis to elicit utilities and probabilities.



### C. Highlights of Research Accomplishments

1. Tversky, A. & Kahneman, D. Judgment under uncertainty: Heuristics and biases. Technical Report, August, 1973. Also published in Science, 1974, 185, 1124-1131.

This article describes three general heuristics (mental operations) that are used to assess probabilities and to predict numerical values.

(i) An assessment of representativeness or similarity, which is usually performed when people are asked to judge the likelihood that an object or event A belongs to a class or process B. (ii) An assessment of the availability (imaginability, memorability) of instances or scenarios, which is often employed when people are asked to assess the frequency of a class or the plausibility of a particular development. (iii) An adjustment from a starting point, which is usually employed in numerical prediction when a relevant value is available. These heuristics lead to systematic and predictable errors by both laymen and experts. The insights provided by this paper should be a major step towards improving judgments and decisions in situations of uncertainty.

2. Slovic, P. & Tversky, A. Who accepts Savage's axiom? Technical Report, February, 1974. Also published in Behavioral Science, November, 1974.

This paper questions the acceptability of the axioms of rational decision making. In particular, this study scrutinizes Savage's "Independence Principle" which asserts that, if two competing decision alternatives have a common outcome under a particular state of affairs, then the preference for one or the other alternative should be independent of the value of that common outcome. Persistent violations of this axiom were observed. Such violations raise doubts about the very foundation of modern decision analysis--i.e., about the validity of expected utility theory. These violations suggest that psychological considerations such as regret and distaste for ambiguity may have to be incorporated into



utilities, making such utilities context dependent. This implies that utilities measured out of context may not be valid bases for decision making.

3. Lichtenstein, S., Earle, T., & Slovic, P. Cue utilization in a numerical prediction task. Technical Report, February, 1974. Also published in Journal of Experimental Psychology, February, 1975.

This study describes a non-optional procedure used by judges when making predictions on the basis of two independent, numerical cues. Whereas the optimal (statistical) model for this task adds the separate impacts of each cue, almost every judge averaged the two cues, leading to serious errors of prediction. This result demonstrates the need for special training or decision aids for persons involved in making predictions from quantitative data.

4. Slovic, P. Consistency of choice between equally-valued alternatives. Technical Report, November, 1974. Also in press, Journal of Experimental Psychology.

What happens when a decision maker is faced with a choice between two alternatives that are of equal value to him? This study shows that people resolve such dilemmas by using a choice rule that is easy to apply and easy to justify to themselves and others. In this case, they consistently chose on the basis of the alternative that was superior on the more important attribute or dimension, even though it was considerably inferior on a lesser dimension. It may be possible, using the knowledge gained from this study, to predict how conflicted individuals (or perhaps even nations) will resolve difficult choices.

5. Fischhoff, B. & Beyth, R. I knew it would happen--remembered probabilities of once-future things. Technical Report, May, 1974. Also published in Organizational Behavior and Human Performance, February, 1975.

In this study judges who had estimated the likelihood of various possible outcomes of President Nixon's trips to Peking and Moscow were unexpectedly asked to recall their own predictions some time after the

visits were completed. In addition, they indicated whether or not they thought that each event had in fact occurred. Remembered probabilities were generally higher than the originally assigned probabilities for events believed to have occurred and lower for those which had not occurred. Judging by their remembered probabilities, subjects seldom perceived having been very surprised by what had or had not happened, thus exhibiting an "I knew it all along" attitude. The practical implications of this result are discussed in Study 7 below.

6. Fischhoff, B. Hindsight  $\neq$  Foresight: The effect of outcome knowledge on judgment under uncertainty. Technical Report, April, 1975. Also in press, Journal of Experimental Psychology.

Several experiments demonstrate that learning some event has happened increases its perceived inevitability. We are unaware, however, of this effect of outcome knowledge and tend to believe that this inevitability was apparent in foresight, before we knew what happened. In retrospect, we tend to believe that we (and others) had a much better idea of what was going to happen than we (or others) actually did have. Such misperceptions can seriously prejudice the evaluation of decisions made in the past and limit what is learned from experience.

7. Fischhoff, B. Hindsight: Thinking backward? Technical Report, November, 1974.

This report provides a non-technical summary of Studies 5 and 6 above. In addition, it presents some specific techniques for evaluating the quality of decision making without prejudice due to knowledge of results. These include (a) educating the evaluators with regard to the existence and nature of uncertainty in the past; (b) generating alternative futures for past situations; and (c) farming the evaluation out to genuinely foresightful minds (ignorant of the decision outcome). Examples of possible hindsight biases in evaluating military, socio-political, and personal decisions are discussed here.

8. Fischhoff, B. Temporal setting and judgment under uncertainty. Technical Report, April, 1975. Also in press, Organizational Behavior and Human Performance.

Are probability estimates affected by the temporal setting (i.e., past vs. future) of the events being judged? It has been hypothesized that analysts are more certain about the likelihood of events set in the past than about events set in the future. Experiments reported here show that, when outcome knowledge is withheld from judgments set in the past, temporal setting has no discernible effects on probability estimates.

9. Lyon, D. & Slovic, P. On the tendency to ignore base rates when estimating probabilities. Technical Report, April, 1975.

A fundamental principle of the normative theory of prediction is that prior probability, which summarizes what we knew before receiving any specific evidence, remains relevant even after such evidence is obtained. However, as this study and previous work by Kahneman and Tversky show, human intuition does not work this way. Human judges deviate from the normative model by relying almost exclusively on the implications of specific evidence (i.e., the witness said X; and the message said Y, etc.) and neglecting prior probabilities (i.e., X and Y are very rare in the population of behaviors under consideration). As a result, intuitive probability assessments often are quite erroneous. We show that experts, too, are susceptible to this bias and it is apparent that training and use of special computational techniques must be employed to minimize its effects.

10. Fischhoff, B. Attribution theory and judgment under uncertainty. Technical Report written and being prepared for distribution, July, 1975.

A central activity of any intelligence-gathering operation is understanding why various people acted as they did, i.e., attributing causes to their behavior. The quality of these attributions sets an upper limit on the quality of the interpretation of more complex (global) events inferred



from them. Identification of systematic biases in attributional behavior would suggest ways in which an intelligence-gathering operation could improve its performance. In this paper, the extensive psychological literature on attributional behavior is reviewed, revealing a number of interesting biases. For example, people will frequently attribute a given act to circumstantial constraints when they are the actor, but to personal traits when they are the observer. In general, however, the "attribution theory" literature is largely devoid of applied ramifications, generally ignoring questions of attributional adequacy. Ways to remedy this problem and to further our understanding of how well people make attributions are suggested. Considerable attention is given to how we may increase the positive transfer between prediction and explanation.

11. Fischhoff, B & Lichtenstein, S. Don't attribute this to Reverend Bayes. Report submitted for journal publication.

Ajzen and Fishbein (1975) have recently offered the rules of Bayesian inference as a unifying framework for research on attribution processes. The usefulness of their theory, however, is restricted by errors and ambiguities in their presentation of Bayesian inference, by their inadequate review of the empirical evidence regarding the extent to which people follow Bayes' theorem in intuitive information processing, and by their misapplication of Bayes' theorem to attributional tasks. A number of these flaws are pointed out and an alternative manner of exploiting Bayesian inference is suggested.

12. Slovic, P., Fischhoff, B. & Lichtenstein, S. Cognitive processes and societal risk taking. Technical Report completed and about to be distributed. July, 1975.

This paper explores how the psychological study of decision processes might help those who seek to understand and improve societal decisions involving risk. The discussion is organized around three questions: (a) What are

some of the basic policy issues regarding societal risk? (b) What knowledge has 25 years of empirical and theoretical research produced that is relevant to these issues? (c) What more do we need to know and how might we acquire that knowledge?

#### D. Work in Progress

In addition to the studies summarized above, work has been proceeding on many other studies of judgmental biases and their implications for improving human decisions. This work will be continued and completed under our new contract.

1. A study by Tversky and Kahneman is attempting to demonstrate the workings of anchoring and adjustment processes in the assessment of subjective probability distributions. Tentative conclusion: Assessed probabilities are so greatly affected by response mode that one should average across several assessment techniques, with opposing biases, to minimize distortion.

2. Slovic has been evaluating the effectiveness of various forms of computerized feedback in teaching people to integrate information in complex ways when making a quantitative judgment or prediction. Tentative conclusion: Computerized feedback, which transforms conceptual judgment problems to perceptual tasks, may enable people to perform far more complex judgment tasks than had previously been thought possible (where complex means many predictor cues, differing in importance, and each having a different, often nonlinear, relationship to the criterion being judged).

3. Tversky and Kahneman are preparing a treatise on "The psychology of regret." This study will illustrate the psychological components of utility much as their earlier work documented the components of subjective probability. They will attempt to demonstrate that psychological components such as anticipated regret must be incorporated into utilities if these utilities are to be valid guides to decision.

4. Lichtenstein and Fischhoff have been studying the adequacy of individuals as probability assessors and the possibility of developing aids to help them become better calibrated.

5. Slovic, Lichtenstein and Fischhoff have been studying persons' perceptions of the relative frequencies of low probability hazards such as causes of death. Results indicate that people have consistent subjective orderings for such events, but these orderings often differ markedly from the statistical frequencies.

6. Kahneman and Tversky are completing a critique of utility theory entitled "Value theory: An analysis of choices under risk". This paper points out the inadequacies of utility as a descriptive model for choice under uncertainty and as a normative or prescriptive model as well. Their findings bring into question the techniques used by decision analysts to infer subjective probabilities and utilities from observed preferences. "Value Theory" is developed as an alternative to utility theory.